International Journal of Pedagogy and Teacher Education

Journal Homepage: jurnal.uns.ac.id/ijpte

Technological Pedagogical Content Knowledge (TPACK) Framework for Science Teachers' Comptences in Facing Global Challenges and Issues: A Narrative Literature Review

Abdul Latip [1*], Babang Robandi [2], Amaliah [3], Rifqi Rohmanul Khakim [4], Nurul Fatonah [5]

[12]Universitas Pendidikan Indonesia, [3]Universitas Katolik Atma Jaya, [4]Universitas Brawijaya, [5]Universitas Garut, Indonesia

[1] **ARTICLE INFO**

Article History
Received : 2023-06-08
1st Revision : -
Accepted : -
Available Online : -

Keywords:
TPACK;
teacher competency;
global issues.

Corresponding Author
Email address:
abdullatip@uniga.ac.id

ABSTRACT

Technological developments have made technology-assisted learning an essential part of educational areas. However, integrating technology in education requires teachers' competency, called technological pedagogical content knowledge (TPACK). This study reviews the current body literature of TPACK regarding teachers' challenges and demands of learning with global issues, such as the Industrial Revolution 4.0 and the SDGs 2030 agenda. Researchers employed Narrative Literature Review (NLR), where we reviewed TPACK, teacher competence, and challenges to global issues in education studies from various published articles. This study found a total of 27 articles published in the last ten years. In this study, NLR was carried out in 4 main stages: determining the topic, finding sources and references, analyzing relevant sources, and synthesizing the findings into a structured and informative narrative. The NLR results show that: 1) the form and type of technology integration in education needs to pay attention to aspects of pedagogy and content knowledge so the determination and use of technology in education can work effectively according to the characteristics of students and the content being taught; 2) forms and types of technology integration have been used include virtual labs, molecular and particle animation media, smartphone applications, and augmented reality; and 3) technology integration in the learning process indicated initial, core, and closing activities requiring various approach. Utilizing technology in education within the initial, core, and closing activities requires considering type and form of technology used according to pedagogical aspects (setting learning objectives) and content aspects (depth and breadth of material at each stage). The study results highlighted teachers' competencies on TPACK to effectively support teaching and learning processes in alignment with global needs and challenges.

How to cite: Latip, A., Robandi, B., Amaliah, A., Khakim, R. R., & Fatonah, N. Technological Pedadogical Contents Knowledge (TPACK) Competency Framework for Teachers in Facing Global Issue Challenges: A Narrative Literature Review. *International Journal of Pedagogy and Teacher Education, 7*(1), 45-57. https://doi.org/10.20961/ijpte.v0i0.74699

1. INTRODUCTION

Teacher competence plays a pivotal role in the educational process, garnering attention from all parties, including stakeholders and implementers. Teacher competence stands as one of the determining factors in achieving success within the learning process. Furthermore, teacher competence can lead to fostering teacher professionalism, which serves as the key to encouraging the overall quality of education (Efrilia, 2020). In pursuit of efforts to develop teacher competencies and professionalism, various programs have been implemented by the government and other institutions or agencies. In the Indonesian context, the government has established a teacher professional program (PPG) to nurture teacher competencies.

The government, agencies, and non-governmental organizations developed teacher provisional development programs per se. Interestingly, they have also rebranded PPG into various programs, such as training, workshops, and webinars. These endeavors prepare teachers with multiple teaching skills to upgrade

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

themselves and be more adaptive to the changes and developments of the contemporary era. Ensuring teacher provisional development quality in practice requires more than certified knowledge and qualification driven. Nonetheless, it necessitates sustainable development to encompass human development, technology, and global issues for a more profound understanding (Subramanian et al., 2022). Furthermore, teachers must also possess some competencies in dealing with the ever-evolving globalization of education, such as developments in student characteristics, diverse classroom dynamics, and a wide range of learning settings (Auziņa, 2018).

In a broader context, global issues and international agendas require teachers to continue to improve their competence and professionalism. These global issues include the 2030 SDGs agenda, especially SDG number 4, which relates to the quality of education requiring teachers to improve their competence, especially technological competence (David & Miriam, 2022). Another global issue that demands teachers to enhance their competence is the Industrial Revolution 4.0. The Industrial Revolution 4.0 impacts rapid growth of technological developments, so the teacher's role in using technology in the learning process needs to be increased (Indira et al., 2020). These two global issues lead to challenges and demands for teachers to improve technology competencies for teaching, especially the use and development of technology to help students enhance their learning and engagement.

The use of technology in education has rapidly begun during the COVID-19 pandemic because of high demand for using technology. However, using technology in education is not simply using and integrating media or technology-based aids in learning without considering students' circumstances, learning strategies, and learning content. Although technology integration into learning reported a positive impact, the integration of technology did not automatically support learning (Walan, 2020). Moreover, successfully using technology in education requires careful preparation in integrating technology based on pedagogical aspects and material designs (Janssen et al., 2019). We argue that a teacher must be competent in incorporating technology with pedagogical aspects and curriculum content, known as Technological Pedagogical content knowledge (TPACK).

The TPACK framework is vital in achieving effective technology integration in the learning process by strengthening the application of instructional strategies and curriculum development (Liunokas et al., 2021). However, only a minority of teachers had sufficient competencies in TPACK (McKenney & Voogt, 2017). Several studies have demonstrated that teachers' competence is still required for enhancement, both in technological content knowledge (TCK) and technological pedagogical knowledge (TPK) (Hasanah et al., 2022; Nurruzakiah et al., 2022; Handika et al., 2023). The significance of enhancing teachers' competencies on TPACK (e.g., TCK and TPK) is due to the rapid development of technology in education and the demand for implementing learning to meet the needs of the digital community. Moreover, the status quo challenges teachers to improve competence on TPACK in dealing with global issues, especially the SDG agenda and the Industrial Revolution 4.0, which demands the actual practices of technology.

Therefore, this paper discusses teacher challenges in dealing with global issues, especially from the perspective of the TPACK framework. Moreover, the distinctive content characteristics in various subjects in teaching require teachers to deliver material according to their modes of communication, especially when using technology in learning. Furthermore, students' distinct factors necessitate that teachers be aware of teaching methods tailored to the individual student's needs and use suitable technologies to accommodate concepts to engage students with the material. Thus, TPACK empowers teachers to provide 21st-century learning skills and prepare them to face global challenges.

2. MATERIAL AND METHODS

This research uses the Narrative Literature Review (NLR) method. Ford (2020) says a narrative literature review is qualitative research focusing on telling a topic concerned with transferring knowledge as a literature review or reference. NLR in this study consists of 4 stages: 1) determining the case, 2) finding sources and references, 3) analyzing relevant authorities, and 4) synthesizing the findings into a structured and informative narrative. This study's keywords employed at the reference search stage were 1) TPACK, 2) global issues, and 3) technology-based learning media. We used the "publish or perish" application to obtain the database, and we found 100 articles by using those keywords. We also employed inclusion and exclusion criteria, including 1) the article has a clear and focused connection and relevance to the theme, 2) the article is published in a nationally indexed journal (Sinta) and Scopus, and 3) the article is published from 2014-2023. After applying these criteria,

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

we found 27 articles focusing on theme (see Table 1). The following maps the analyzed articles based on their respective themes and authors.

Table 1. The theme of the article and the name of the author

No	Article Theme(s)	Author(s)
1	TPACK	Absari, et al., David, M., & Miriam, M., Efrilia., Indira, E. W, et al., Janssen, N, et al., Liunokas, S. M, et al., McKenney, S., & Voogt, J., Shing, C. L, et al., Subramanian, et al., Zhang, W., & Tang, J., setiawan, et al., Hasanah, et al.
2	Kind of Learning Media	Aljuhani, K, et al., Echeverria, A, et al., Hernawati, D, et al., Yilmaz, O. Narulita, et al. Boston dan Sener., Gestiadi, et al., Ipin, et al.
3	Global issues	Auziņa, A., Education Endowment Foundation., Lev, T. A., Puertas-Aguilar, M. Á, et al., M. L., Walan, S.,

We employed descriptive analysis of each article and grouped them according to themes. Our descriptive explanations also mapped prior studies regarding 1) finding results and 2) theoretical framework. Descriptive explanations of the analysis results from each article were synthesized to provide informative and well-structured descriptions.

This analysis and synthesis provided in-depth descriptive explanations of the teacher's competency on TPACK in dealing with global issues in education, focusing on integrated aspects of content, pedagogy, and technology.

3. RESULTS AND DISCUSSION

Development and Transformation of PCK to TPACK

Pedagogical Content Knowledge (PCK) was first introduced as a competency framework that must be embedded in teachers in Shulman (1986) who emphasized two core elements, namely the ability to represent content and knowledge of the difficulties experienced by students in specific materials. Since then, the development of the PCK framework has continued evolving regarding Shulman's PCK model. Grossman (1990) emphasized four main components in PCK, namely: 1) understanding of learning objectives, 2) knowledge of students' conceptions, perceptions, and misconceptions about particular materials, 3) mastery of the curriculum, in this case, subject matter, and 4) knowledge of learning strategies.

Meanwhile, Cochran (1993) criticized Shulman's PCK model, which was considered static, even though this PCK would continue to develop along with the development of students and the learning environment. Furthermore, the teacher's PCK continued to evolve along with the teachers' experiences and roles. Moreover Veal and MaKisnter (1999) explained the PCK taxonomy, demonstrating that content knowledge (CK) was the primary source for building teachers' PCK competencies. It is strengthened by teachers' knowledge about students and eight other PCK elements, such as the learning environment, context, curriculum, class management, etc.

The evolvement of education's challenges and changes made teachers' insufficient PCK competence hinder teachers' capacity to teach. Pierson (2021) added technology to PCK with the term "Technology assisting PCK," which described a set of knowledge and skills needed by a teacher in teaching specific subjects at a certain level. TPCK was introduced as a competency framework. Moreover, teachers must possess those competencies (Mishra and Kohler, 2006). It was refined by adding the letter "A", known as TPACK. Adding the letter A did not just make it easier to pronounce; it emphasized the complete integration and interaction between pedagogy, content, and technology in a competency framework (Mishra and Kohler, 2007).

Global issues' rapid developments and challenges enhanced teachers' technological competence, making TPACK even more critical for teachers. Furthermore, the COVID-19 pandemic has provided a significant

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

technological experience for teachers. Where teachers did not expect to teach in digital circumstances, it required teachers to adapt responsively to continue learning. In addition, other global issues, such as the Industrial Revolution 4.0 and the SDGs agenda, challenge teachers to respond by increasing technological competence in learning.

Teacher Competency on TPACK Framework in Facing Global Issues

In this section, we discussed the TPACK framework and its elements related to the challenges of global issues. However, before elaborating on the TPACK framework, the following is the PCK framework, which is an integral part of the TPACK framework:

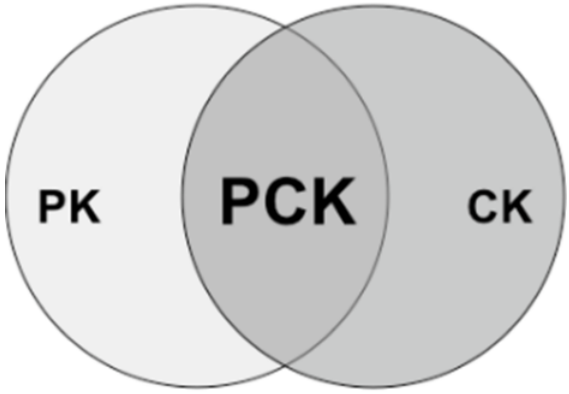

Figure 1 PCK model from Shulman

Shulman's **(1986)** PCK model emphasizes three main competencies, namely:

1. Pedagogical Knowledge (PK) is a teacher's competence regarding knowledge and skills regarding learning strategies that suit the needs and characteristics of students. For this PK competency, teachers need to understand the four components of the curriculum, which include learning objectives, content, learning strategies, and learning evaluations. Furthermore, teachers must also understand students' psychological and cognitive development to support better PK competencies. This understanding of student development can be an asset for teachers to map students' abilities and needs to determine appropriate learning strategies according to the characteristics of students at each level.
2. Content Knowledge (CK) is a teacher's competence in mastery and knowledge of material content according to their field. Knowledge of this content is about more than just mastering and understanding the content. A teacher must also master the material's structure to map the content in depth and breadth.
3. Pedagogical Content Knowledge (PCK) is a teacher competency that integrates pedagogical knowledge and content knowledge. In this PCK, a teacher must understand the curriculum content structure and determine appropriate learning strategies according to the characteristics of the content, students, and other aspects (Shulman, L., 1986).

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

Meanwhile, the TPACK framework has four additional competencies besides PK, CK, and PCK. The following is the TPACK framework modeled on Mishara and Kohler:

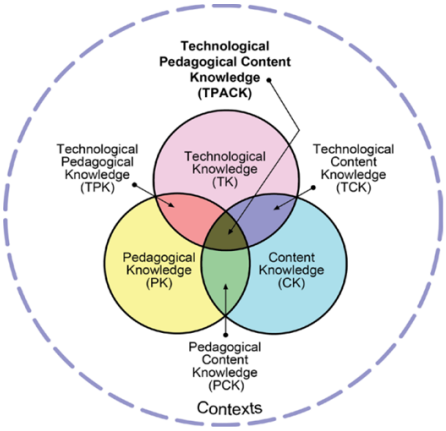

Figure 2. TPACK Framework from Mishra and Kohler (Kohler, Mishra, & Cain., 2013, p 12-14)

The four competencies that must be mastered by teachers besides PK, CK, and PCK are contained in the TPACK framework as follows:

1. Technological Knowledge (TK) is a competency related to the teacher's knowledge of the types and forms of technology that can be integrated into the curriculum or teaching. This technology includes knowledge of hardware that can support education, as well as software that can help facilitate and expedite teaching process (Kohler, Mishra, & Cain., 2013, p 12-14)
2. Technological Content Knowledge (TCK) is a competency that requires the interaction between technological capabilities and content knowledge. In selecting or developing technology to be used in teaching, it is necessary to analyze and map curriculum content so that the technology used or integrated into education supports students' understanding and engagement of the content presented (Kohler, Mishra, & Cain., 2013, p 12-14).
3. Technological Pedagogical Knowledge (TPK) is a competency that emphasizes the importance of integrating technological knowledge and pedagogy in teaching. In choosing the form and type of technology to be integrated into education, teachers need to understand learning strategies and the needs of students both psychologically and cognitively so the technology used can suit the needs and characteristics of students (Kohler, Mishra, & Cain., 2013, p 12-14).
4. Technological Pedagogical Content Knowledge (TPACK) is a complete competency that describes the interaction between pedagogy, content, and technology knowledge so it can develop teachers' technology-integrated awareness according to the content's demands and the students' characteristics and needs (Kohler, Mishra, & Cain., 2013, p 12-14).

The TPACK needs to be continuously developed so teachers can face the challenges and demands of educational development nationally and globally. A global concern to develop teachers' competencies on TPACK is regarding the 2030 SDGs agenda and the 4.0 industrial revolution. To tackle these global issues effectively, teachers must improve their technology and digital literacy skills linked to pedagogical and content abilities. The following table shows the TPACK framework in dealing with the SDGs agenda and the Industrial Revolution 4.0.

Table 2. Global Issues and Teacher Competency on TPACK Framework

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

No	Global issues	Teacher Competency on TPACK Framework
1	SDGs Agenda	The results of a literature review of several articles show that in dealing with the SDG agenda, especially SDG point 4 regarding the quality of education, teachers are required to have digital competence in developing learning models and media so that they can contribute to improving the quality of learning and offering broad learning opportunities (Méndez D, Méndez M, Anguita JM., 2022); Puertas-Aguilar et al., 2021). Four important recommendations need to be considered in the use of technology to improve the quality of Learning (Lewin, C., Smith, A., Morris, S. and Craig, E., 2019), namely: 1. Consider the use of appropriate technology so it can suit learning needs before using it. Related to the TPACK framework, it is emphasized that technology must be carefully planned, considering pedagogical aspects and students' needs. 2. Technology must be used with an orientation to improve the explanation and modeling of a concept. This recommendation illustrates that the use of technology in education must pay attention to the characteristics and structure of the content in the curriculum. Hence, technology use becomes a tool that can facilitate students in explaining and modeling a concept. It is aligned with the TPACK framework, which requires pedagogy, content, and technology interaction. 3. Technology must offer ways for students to increase practical impact sustainably. This recommendation emphasizes that the technology must equip students with practical skills that can be used in other contexts and situations. In other words, using technology in education is expected to improve students' competencies. For instance, digital competencies can be used in everyday life. 4. Technology must have a role in improving the quality of assessment and feedback according to pedagogical aspects and curriculum content. This recommendation emphasizes two parts of technology integration, including 1) in the teaching-learning process and 2) in the assessment process.
2	Industrial Revolution 4.0	The Industrial Revolution had an impact on various fields, including education. The rapid development of technology in the era of the Industrial Revolution 4.0 requires teachers to improve their competence. Four teacher competencies need to be enhanced (Indira et al., 2020), namely: 1. Basic skills in teaching and using the internet in education. Regarding the TPACK framework, basic skills are closely related to pedagogical and content competencies. At the same time, using the internet in learning is part of technology skills. Thus, in the era of the Industrial Revolution 4.0, a teacher must be able to package learning content by pedagogical aspects that utilize the internet to support learning. 2. Technological competence for commercialization. At this point, it emphasizes that a teacher is expected to have competence in using technology that can encourage students to innovate so they can produce artistic and economic value works. 3. Global competence. This competency synergizes that teachers must have a global mindset. This competency requires teachers to be able to relate material content to the worldwide context that occurs in various countries.

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

No	Global issues	Teacher Competency on TPACK Framework
		4. Skills as a counselor. This competency explains that a teacher must be able to understand students' problems in addition to understanding content knowledge. Teachers can map students' needs and characteristics to design the best learning processes and technology forms. In this regard, teachers are expected to improve teaching strategies in facing the Industrial Revolution 4.0, where they need to be adaptive to technology and increase their pedagogical knowledge and curriculum content. A comprehensive understanding of technology, pedagogy, and content can lead teachers in dealing with the Industrial Revolution 4.0 challenges.

The Kind of Technology Integration in Learning according to the TPACK Framework

The effectiveness of technology integration in teaching process indicated the type and form of integrated technology used for students' learning process outcomes. In addition, technology integration also takes into consideration curriculum framework and student characteristics demands. Therefore, selecting forms and types of technology to be integrated into teaching process can only be done with careful consideration and preparation (Absari et al., 2020). Teacher competencies on the TPACK framework helped present technology integration suitable for learning needs. The following maps our search results for reference sources published from 2013-2023. Furthermore, those articles are used as material for analysis for NLR with a focus on teacher competencies on TPACK in science learning.

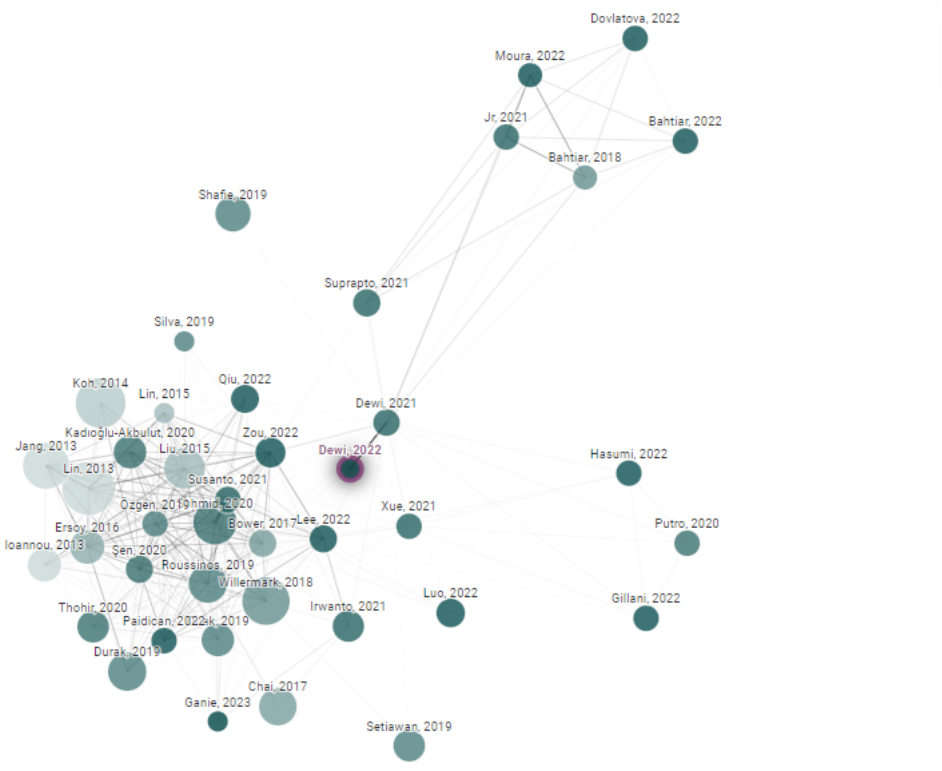

Figure 3. Mapping results with a connected paper regarding teacher competencies on TPACK in science learning

Based on the analysis of mapped articles, it is evident that various forms and types of technology are used in science learning. We provided forms and styles of technology that can be integrated into teaching by paying attention to the TPACK framework for teacher competency.

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

Virtual Labs

The virtual lab is a learning platform with a laboratory approach to introduce and carry out practicum in a safer, more interactive lab environment (Aljuhani et al., 2018). Utilization and use of virtual labs in learning, especially in science subjects, were limited to certain materials or practicum topics. By paying attention to content, pedagogical, and technology aspects, the teacher's competence plays a vital role in selecting the type of virtual lab and science material to implement meaningful learning (Narulita et al., 2019). In determining and utilizing the virtual lab, several conditions need to be considered, namely as follows:

1. Practicum content or topics can only be assessed indirectly when the practicum is conducted in the laboratory. In the context of the science practicum, several contents or practicum topics pose safety risks if teachers teach students to use hazardous chemicals in the laboratory.
2. The inadequate availability of tools and materials, both in quantity and at an unaffordable price, could be facilitated and tackled by application. The tools and materials were demanded to be obtained by the school, so it is difficult to practice in the laboratory for some particular practicum topics. Moreover, expensive tools and materials are required for practicum activities, so they cannot be afforded. These two conditions cannot prevent practicum activities, so an alternative can be done using a virtual lab.
3. Limited time for practical implementation takes a long time for some content and specific practicum topics, so it is impossible to carry it out directly in the laboratory. To anticipate this, a virtual lab can be an alternative practicum activity with implementation adjusted to the availability of practicum time while not eliminating the essence of a series of practicum activities.

These conditions indicate that using virtual labs in the learning process requires considering aspects of scientific content and material, and the virtual lab selection interacts with the TPACK frameworks: TK and CK. Furthermore, apart from considering TK and CK, teachers must also pay attention to pedagogical aspects of using and utilizing virtual labs in the learning process, such as learning objectives or practicum activities.

Molecular or particle animation

Science is built with three levels of representation, namely the macroscopic, sub-microscopic, and symbolic levels. These characteristics make the learning accommodate the three representation levels through various strategies, models, and media. The sub-microscopic level is abstract and requires technology-based media to represent it. Molecular and particle animation can be an alternative for explaining the sub-microscopic level of a particular material or content.

The use of molecular and particle animation-based media in science teaching necessitates attention to the characteristics of the material. In this case, molecular or particle animation media requires content and material analysis. In addition, molecular and particle animation must also consider students' cognitive development levels. This is based on the various cognitive abilities of students, so the animation is used regarding students' needs and thinking levels.

Android application-based media

The development of technology into a communication tool such as mobile phones is not only used to communicate. Nowadays, cell phones have led to other functions, so they are often referred to as smartphones. Smartphones are currently widely used in learning through various special features or applications. Smartphones in the learning process are based on pedagogical aspects, namely the characteristics of current Z or alpha generation group students. Generation Z has characteristics such as fast-response learners who are comfortable, proficient, and competent in digital and visual environments (Lev, 2021).

To facilitate student learning styles, smartphones can be utilized to support learning activities in class. In this context, teachers are required to select the forms and types of technology that can be integrated into education using smartphones (Boston & Sener, 2021). Technology integration in smartphones that could be used in science learning called INaturalist, which is used in learning vertebrate material (Hernawati et al., 2020),

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

learning about plants (Echeverria et al., 2021), and learning diversity (Lucas et al., 2023). The following is an example of an overview of the INaturalist application used in biology lessons.

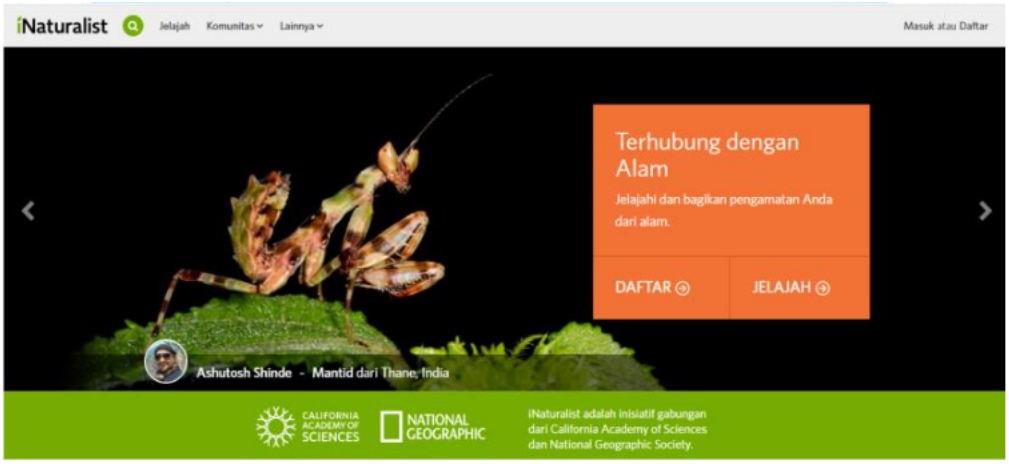

Figure 4. The I-Naturalist Application on Smartphones for Biology Learning (Ipin et al., 2023)

Using INaturalist integrated with pedagogical aspects allows teachers to construct students' characteristics and learning strategies so students can benefit from this application in the learning process. In addition, in using INaturalist, teachers should pay attention to various elements of communicating material or content so teachers can select that the application can cover material that students must master and their learning styles.

Augmented Reality (AR)

Using smartphones in the learning process has also leveraged Augmented Reality (AR) to illustrate virtual objects that emerged in the real world by capitalizing on the sophistication of smartphones. The research results on AR in science learning show that this AR can detect weaknesses in students' understanding of a concept, reduce student misconceptions, and help students learn abstract concepts (Yilmaz, 2021). The following is an example of an illustration of the use of AR in Learning:

Figure 5. Use of AR in Learning (Yilmaz, 2021)

AR in learning certainly pays attention to the TPACK framework. The pedagogical aspect provided an overview of the characteristics of students who can use this AR. The part of content also needs to be considered because not all content or material cannot be simulated in AR (Gestiadi et al., 2022).

Technology Integration in the Learning Process Based on the TPACK Framework

Technology integration in the learning process based on the TPACK framework can be categorized according to the objectives and the type of learning process carried out in class. Teachers with sufficient competence on

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

TPACK have capacities to choose the right technology in the learning process according to students' needs (Setyowati & Rachmajanti, 2023). The following is a form of technology integration in the learning process according to the TPACK framework.

Table 3. Technology Integration in the Learning Process in the TPACK Framework

No	Type of Learning Process	Content Characteristics	Types of Technology Integration
1	**Apperception:** In this process, technological assistance is intended to students' prior knowledge so students are interested in learning.	The content presented in the apperception activity is associated with students' prior knowledge that is related to new knowledge. The nature of the content requires to be expanded with more profound exploration.	In apperception, technology integration can be done by showing videos about phenomena from prior material. In addition, the apperception process can also display lighter or stimulant animations so students are interested in the material.
2	**Core activities:** In this process, technology is intended to clarify a concept or content that is abstract, complicated, and complex. In addition, the use of technology in this process is also planned so students do not get bored with learning.	The content in the core activities has entered the important content of the material being studied. In the process, the content presented can be abstract, complex, or complex.	The forms and types of technology integration in this process include: ● To explain abstract material, teachers can use animation. ● To present complex material, teachers can use animation or video shows. ● To define complex material, animation and video can be used. ● To make learning more varied for students, the types and forms of integration that can be used are Android applications in the form of games or other things.
3	**Closing activities:** Technology is intended to stimulate learning feedback in this process.	The characteristics of the content in this process are more about conclusions and evaluation of the material that has been studied.	Forms and types of technology integration that can be used in closing activities include: ● Teachers can use a short video or a short animation to provide a stimulus in concluding material. ● To evaluate and give feedback, teachers can use applications, such as quizzes and Kahoot.

4. CONCLUSION

The TPACK framework is needed for teachers to face the challenges and demands of learning with global issues, such as the Industrial Revolution 4.0 and the SDGs 2030 agenda. One of the emphases on these two global issues is that teachers must prepare themselves by increasing digital competence. Moreover, the form and type of technology integration in learning need more attention to aspects of pedagogy and content so the determination and use of technology in education can run effectively according to the characteristics of students and the content being taught.

Technology integration forms and types in science include 1) virtual labs, 2) molecular and particle animation media, 3) smartphone applications, and 4) Augmented Reality. Technology integration in the learning process can be approached from initial, core, and closing activities, but it requires a different approach. In the initial, core, and closing activities, the integration of technology used in the process could vary in type and form according to pedagogical aspects (setting learning objectives) and content aspects (depth and breadth of material

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

at each stage).

The study with NLR had some limitations, including 1) the reference sources or articles analyzed focused on the TPACK of teacher competence in a teaching science field; 2) the TPACK discussed focus on teacher challenges in dealing with global issues (e.g., the 2030 SDGs agenda and the industrial revolution 4.0); and 3) the type of technology integration discussed limited to the teacher's TPACK and learning impact. Therefore, future studies could explore the development and technology integration processes.

REFERENCES

Absari, et al. (2020). The Effectiveness of Technology, Pedagogy and Content Knowledge (TPACK) in Learning. *Jurnal Pendidikan Teknologi dan Kejuruan.* 26(1), 43-51. https://doi.org/10.21831/jptk.v26i1.24012

Aljuhani, K., Sonbul, M., Althabiti, M., & Meccawy, M. (2018). Creating a Virtual Science Lab (VSL): adopting virtual labs in Saudi schools. *Smart Learning Environments*, *5*(1). https://doi.org/10.1186/s40561-018-0067-9

Auziņa, A. (2018). Teacher Competences for Facing Challenges of Globalisation in Education. *Journal of Education Culture and Society*, *9*(2), 24–37. https://doi.org/10.15503/jecs20182.24.37

Boston dan Sener. (2021). The Role of Technological Pedagogical Content Knowledge (TPACK) of English Teachers on High School Learners' Acceptance of Mobile Learning Tools. *Shanlax International Journal of Education*. 9(1) 42–52. https://doi.org/10.34293/education.v9iS1-May.3998

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of Teacher Education*, 44(4), 263-272. https://doi.org/10.1177/002248719304400

Echeverria, A., Ariz, I., Moreno, J., Peralta, J., & Gonzalez, E. M. (2021). Learning plant biodiversity in nature: Using the citizen–science platform naturalist as a collaborative tool in secondary education. *Sustainability (Switzerland)*, *13*(2), 1–12. https://doi.org/10.3390/su13020735

Efrilia. (2020). Relationship of teacher competency test and teacher performance assessment in increasing education quality. *A Multidisciplinary Peer Reviewed Journal*, *6*(6), 757–766.

Ford, E. (2020). Tell me your story: Narrative inquiry in LIS research. *College & Research Libraries*, *81* (2). https://doi.org/10.5860/crl.81.2.235.

Gestiardi, R., Nurmawati, F., & Atmojo, I. R. W. (2022). Augmented Reality Needs Analysis in Science Learning: Teacher's Perspective. *Al-Ishlah: Jurnal Pendidikan*. *14*(1), 51-60. https://doi.org/10.35445/alishlah.v14i1.935

Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. Teachers College Press.

Handika, R. F., Agustin, M., & Jakawali, G. (2023). TPACK Component Analysis (Technology, Pedagogics, Content Knowledge) in Elementary School Teachers as a Framework for Teacher Competence in 21st-Century Learning. In *International Conference on Elementary Education*, *5*(1), 545-551. Retrieved from http://proceedings.upi.edu/index.php/icee/article/view/3171

Hasanah, et al. (2022). Teacher Competency Analysis in Applying Technological, Pedagogical and Content Knowledge (TPACK) on Productive Learning in Vocational High School (VHS). *International Journal of Social Science Research and Review*, *5*(1), 166-175. https://doi.org/10.47814/ijssrr.v5i1.162

Hernawati, D., Chaidir, D. M., & Meylani, V. (2020). The use of iNaturalist in learning courses of zoology vertebrates for prospective biology teachers. *Journal of Physics: Conference Series*, *1440*(1), 0–5. https://doi.org/10.1088/1742-6596/1440/1/012064

Indira, E. W. M., Hermanto, A., & Pramono, S. E. (2020). *Improvement of Teacher Competence in the Industrial Revolution Era 4.0. 443*(Iset 2019), 350-352. https://doi.org/10.2991/assehr.k.200620.068

Gaffar, A. A., Rizkia, R. F., & Yulianti, D. (2023). Utilizing The iNaturalist Application for Biology Research and Learning. *Jurnal Mangifera Edu*, *7*(2), 83-93. https://doi.org/10.31943/mangiferaedu.v7i2.162

Janssen, N., Knoef, M., & Lazonder, A. W. (2019). Technological and pedagogical support for pre-service teachers' lesson planning. *Technology, Pedagogy and Education*, *28*(1), 115–128. https://doi.org/10.1080/1475939X.2019.1569554

Koehler, M. J., Mishra, P., & Cain, W. (2013). *What is Technological Pedagogical Content Knowledge (TPACK)? Journal of Education, 193(3), 13–19.* https://doi.org/10.1177/002205741319300303

Lev, T. A. (2021). Generation Z: Characteristics and Challenges To Entering the World of Work. *Cross-Cultural Management Journal*, *23*(1), 107–115.

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153

Lewin, C., Smith, A., Morris, S., & Craig, E. (2019). Using Digital Technology to Improve Learning: Evidence Review. *Education Endowment Foundation*. Retrieved from https://educationendowmentfoundation.org.uk/public/files/Using_Digital_Technology_to_Improve_learning_Evidence_Review.pdf

Liunokas, S. M., Louise, I. S. Y., & Sampouw, F. (2021). Chemistry teacher's perception about their technology, pedagogical, and content knowledge (TPACK). In *6th International Seminar on Science Education (ISSE 2020)* (pp. 315-321). Atlantis Press. https://doi.org/10.2991/assehr.k.210326.045

Forti, L. R. (2023). Students as citizen scientists: Project-based Learning through the iNaturalist platform could provide useful biodiversity data, *Biodiversity*, 24(1-2), 76-78, https://doi.org/10.1080/14888386.2023.2174595

McKenney, S., & Voogt, J. (2017). Expert views on TPACK for early literacy: Priorities for teacher education. *Australasian Journal of Educational Technology*, *33*(5), 1–14. https://doi.org/10.14742/ajet.2502

Méndez, D., Méndez, M., & Anguita J. M. (2022) Digital Teaching Competence in Teacher Training as an Element to Attain SDG 4 of the 2030 Agenda. *Sustainability*. *14*(18), 11387. https://doi.org/10.3390/su141811387

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for the teacher knowledge. *Teachers College Record, 108*(6), 1017-1954

Narulita, E., Hariyadi, S., Utomo, A. P., & Fauziah, L. F. (2019). Research-Based Biotechnology Book with Virtual Laboratory for Elevating TPACK of Biology Pre-Service Teacher. I*nternational Journal of Learning, Teaching and Educational Research.* 18(11), 297-310. https://doi.org/10.26803/ijlter.18.11.18

Nuruzzakiah, N., Hasanuddin, H., Artika, W., Supriatno, S., & Rahmatan, H. (2022). Competency Analysis of Technological Pedagogical and Content Knowledge (TPACK) Biology Teachers. *Jurnal Penelitian Pendidikan IPA, 8*(1), 325-335. https://doi.org/10.29303/jppipa.v8i1.1166

Pierson, M. E. (2001). Technology Integration Practice as a Function of Pedagogical Expertise. *Journal of Research on Computing in Education, 33*(4), 413-430. https://doi.org/10.1080/08886504.2001.10782325

Puertas-Aguilar, M. Á., Álvarez-Otero, J., & De Lázaro-Torres, M. L. (2021). The challenge of teacher training in the 2030 agenda framework using geotechnologies. *Education Sciences*, *11*(8). https://doi.org/10.3390/educsci11080381

Setiawan, I., Hamra, A., & Jabu, B. (2018). Exploring A Teacher Educator's Experiences in Modeling TPACK to Create English Language Multimedia in Technology Courses. *Journal of Language Teaching & Research*, *9*(5). https://doi.org/1041. 10.17507/jltr.0905.19

Setyowati, L., & Rachmajanti, S. (2023). The Application of TPACK for Teaching Content Courses: Process, Students' View, and Product in Indonesian Context. *Journal of Innovation in Educational and Cultural Research*, *4*(2), 209-219. https://doi.org/10.46843/jiecr.v4i2.268

Shing, C. L., Saat, R. M., & Loke, S. H. (2015). The knowledge of Teaching-Pedagogical Content Knowledge (PCK). *The Malaysian Online Journal of Educational Sciences*, *3*(3), 40–55.

Shulman, L. S. (1986). Those Who Understand: Knowledge Growth in Teaching. Educational Researcher, 15(2), 4-14. https://doi.org/10.3102/0013189X015002004

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reforms. Harvard Educational Review, 57(1), 1-22. https://doi.org/0017-8055/0200-0001101.25

Subramanian, Muthukumar; Mitra, A. A. R. (2022). *A study on factors affecting teaching competency with special reference to higher*. *January*.

Veal, W. R., & MaKinster, J. G. (1999). Pedagogical content knowledge taxonomies. The Electronic Journal in Science & Mathematics Education, *3*(4). Retrieved from http://unr.edu/homepage/crowther/ejse/vealmak.html

Walan, S. (2020). Embracing Digital Technology. *Journal of Science Education and Technology,29:431–441*, 431–441. https://doi.org/10.1007/s10956-020-09828-6

Yilmaz, O. (2021). Augmented Reality in Science Education: An Application in Higher Education. *Shanlax International Journal of Education*, *9*(3), 136–148. https://doi.org/10.34293/education.v9i3.3907

Zhang, W., & Tang, J. (2021). Teachers' TPACK Development: A Review of Literature. *Open Journal of Social Sciences*, *9*(7), 367–380. https://doi.org/10.4236/jss.2021.97027

p-ISSN: 2597-7792 / e-ISSN: 2549-8525
DOI: https://doi.org/10.20961/ijpte.v0i0.73153